MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2018/2019

ETM7136 – DIGITAL COMMUNICATION SYSTEMS AND DESIGN

(M.Eng.Tele)

26 OCTOBER 2018
2.30 p.m. – 5.30 p.m.
(3 Hours)

INSTRUCTIONS TO STUDENTS

1. This examination paper consists of **7 printed pages** (including the cover page) with **4 questions only**.

2. **Attempt ALL questions.** All questions carry equal marks and the distribution of the marks for each question is given.

3. Please write all your answers in the Answer Booklet provided. **Show all relevant steps** to obtain maximum marks.

Question 1

(a) A digital subscriber line (DSL) modem operates at a signal-to-noise ratio (SNR) of 25 dB and passes data over the frequency range of 2.23 MHz to 105.93 MHz. The DSL modem is to be designed to transmit and receive data simultaneously (i.e. full duplex) over this line without errors.

(i) Calculate the maximum received data rate if the frequency range 2.23 MHz to 53.98 MHz is used for downloading data.

[3 marks]

(ii) Calculate the maximum transmitted data rate if the frequency range 54.50 MHz to 105.93 MHz is used for uploading data.

[3 marks]

(iii) Determine the minimum SNR (in decibels) required for error free transmission if the intended transmission rate for uploading is 400 Mbps and the frequency range for uploading is as in Question 1(a)(ii).

[3 marks]

(b) Compute the normalized power for the following waveforms:

(i) $b(t) = 13\cos(10\pi t)$ for $-\infty < t < \infty$.

[3.5 marks]

(ii) $c(t) = 6\cos(t) + 4\cos(3t)$ for $-\infty < t < \infty$.

[3.5 marks]

(c) Figure Q1 shows the two sided energy spectral density of a waveform $y(t)$.

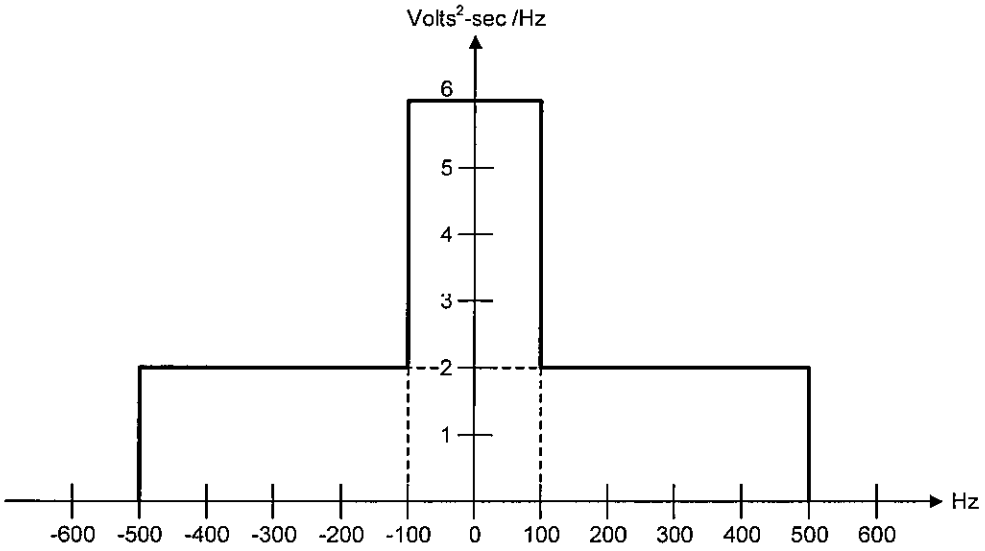

Figure Q1

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Question 1

(c)(i) Calculate the normalized energy of $y(t)$.

[3.5 marks]

(ii) If $y(t)$ is passed through an ideal lowpass filter with a cutoff frequency of 200 Hz, find the normalized energy of the waveform at the output of the filter and the percentage of signal's energy lies in the frequency band passed by the filter.

[3.5 marks]

(d) The autocorrelation function of a signal $w(t)$ is $R_w(\tau) = \frac{A^2}{2}\cos\omega_0\tau$. Determine the average normalized power of $w(t)$.

[2 marks]

Question 2

(a) An analog signal $z(t)$ is to be uniformly sampled for digital transmission using impulse sampling. The signal $z(t)$ can be written as:

$$z(t) = 5\sin(2000t + \pi/6) + 8\cos(4000t + \pi/6) + 10\cos(6000t)$$

(i) Will aliasing occur if the sampling rate f_s is 2 kHz? Justify your answer.

[3 marks]

(ii) Calculate the maximum permissible time interval between sample values that will ensure perfect signal reproduction.

[2 marks]

(iii) Compute the number of sample values required to be stored if the sampling rate f_s is 5 kHz and we want to reproduce 45 minutes of this waveform.

[2 marks]

(iv) Suggest a method to recover the analog signal from the impulse sampled signal.

[1 mark]

(b) An analog signal with maximum frequency of 3 kHz is to be transmitted using a 16-level pulse amplitude modulation (PAM) system. The quantization distortion must not exceed ±0.2% of the peak-to-peak analog signal. Compute the minimum number of bits per sample that should be used in this PAM transmission system.

[3 marks]

(c) Discuss two desirable properties of a line code.

[3 marks]

(d) Explain the working principle of delta modulation in detail.

[4 marks]

Continued...

Question 2

(e) An analog signal $s(t)$ is digitized using a 6-bit pulse code modulation (PCM) and transmitted using binary waveforms over a channel that is bandlimited to 400 kHz. Assume that the overall equivalent transfer function is of the Nyquist type.

(i) Determine the maximum bit rate that can be used by this system without introducing intersymbol interference (ISI).

[3 marks]

(ii) Compute the maximum bandwidth of $s(t)$ that can be accommodated with these parameters.

[4 marks]

Question 3

(a) Matched filter is used to maximize the signal-to-noise ratio (SNR) at the output of a receiver. Explain the relationship of the impulse response of a matched filter with respect to its input signal.

[2 marks]

(b)(i) Describe the main function of a maximum likelihood detector at the receiver.

[2 marks]

(ii) A binary communication system with equally likely signaling transmit signals $s_i(t)$, where $i=1,2$. The receiver test statistic $z(T)=a_i(T)+n_0(T)$, where the signal component $a_i(T)$ is either $a_1(T)=+1$ or $a_2(T)=-1$, and $n_0(T)$ is a zero-mean Gaussian random variable with variance 0.1. Determine the optimum decision rule.

[2 marks]

(c) Explain the differences between frequency shift keying (FSK) and quadrature amplitude modulation (QAM), and discuss the trade-offs that need to be considered when choosing between the two for a particular design.

[5 marks]

(d) A voice-band telephone channel passed the frequencies in the band from 300 Hz to 3300 Hz. It is desired to design a modem that transmits at a symbol rate of 3200 symbols/s, with the objective of achieving 9600 bits/s. Design an appropriate QAM scheme, carrier frequency, and the roll-off factor of a pulse with a raised cosine spectrum that utilizes the entire frequency band.

[9 marks]

Continued...

Question 3

(e)(i) Explain the working principle of block interleaving and state its main advantage in error control coding.

[3 marks]

(ii) Consider a 4×4 block interleaver. Determine the output sequence if the input sequence is 1001010111000101.

[2 marks]

Question 4

(a) Distinguish the following

(i) Automatic repeat request (ARQ) and forward error correction (FEC).

[2 marks]

(ii) Systematic and non-systematic codes.

[2 marks]

(b) The minimum distance for a particular linear block code is 11. Evaluate the maximum error detecting capability and the maximum error correcting capability of this code.

[3 marks]

(c) Consider a Hamming (7,4) code with the generator matrix given by

$$G = \begin{bmatrix} 1 & 0 & 0 & 0 & 1 & 1 & 0 \\ 0 & 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 & 1 & 1 & 1 \end{bmatrix}$$

Compute the syndrome for the received vector 1111000 and determine if an error has occured. If it has, find the correct codeword.

[4 marks]

(d) Consider a convolutional code described by the following generator polynomials:

$$g_1(x) = 1 + x^2,\ g_2(x) = x + x^2$$

(i) Sketch the encoder corresponding to this code.

[3 marks]

(ii) Determine the code rate of this convolutional code.

[1 mark]

(iii) Sketch the state diagram.

[3.5 marks]

(iv) Sketch the trellis diagram.

[3.5 marks]

(e) Consider a telephone modem that operates at 28.8 kbits/s using trellis coded modulation (TCM). Assume that the usable channel bandwidth is 3429 Hz.

(i) Evaluate the bandwidth efficiency of such modem.

[2 marks]

(ii) Give one advantage of TCM.

[1 mark]

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Appendix I: Fourier Transform Pairs

Pair Number	$x(t)$	$X(f)$
1.	$\Pi\left(\frac{t}{\tau}\right)$	$\tau \operatorname{sinc} \tau f$
2.	$2W \operatorname{sinc} 2Wt$	$\Pi\left(\frac{f}{2W}\right)$
3.	$\Lambda\left(\frac{t}{\tau}\right)$	$\tau \operatorname{sinc}^2 \tau f$
4.	$\exp(-\alpha t)u(t),\ \alpha > 0$	$\frac{1}{\alpha + j2\pi f}$
5.	$t \exp(-\alpha t)u(t),\ \alpha > 0$	$\frac{1}{(\alpha + j2\pi f)^2}$
6.	$\exp(-\alpha\|t\|),\ \alpha > 0$	$\frac{2\alpha}{\alpha^2 + (2\pi f)^2}$
7.	$e^{-\pi(t/\tau)^2}$	$\tau e^{-\pi(f\tau)^2}$
8.	$\delta(t)$	1
9.	1	$\delta(f)$
10.	$\delta(t - t_0)$	$\exp(-j2\pi f t_0)$
11.	$\exp(j2\pi f_0 t)$	$\delta(f - f_0)$
12.	$\cos 2\pi f_0 t$	$\frac{1}{2}\delta(f - f_0) + \frac{1}{2}\delta(f + f_0)$
13.	$\sin 2\pi f_0 t$	$\frac{1}{2j}\delta(f - f_0) - \frac{1}{2j}\delta(f + f_0)$
14.	$u(t)$	$(j2\pi f)^{-1} + \frac{1}{2}\delta(f)$
15.	$\operatorname{sgn} t$	$(j\pi f)^{-1}$
16.	$\frac{1}{\pi t}$	$-j \operatorname{sgn}(f)$
17.	$\hat{x}(t) = \frac{1}{\pi}\int_{-\infty}^{\infty} \frac{x(\lambda)}{t - \lambda}\, d\lambda$	$-j \operatorname{sgn}(f) X(f)$
18.	$\sum_{m=-\infty}^{\infty} \delta(t - mT_s)$	$f_s \sum_{m=-\infty}^{\infty} \delta(f - mf_s),$ $f_s = T_s^{-1}$

Continued...

Appendix II: Fourier Transform Properties

Name of Theorem		
1. Superposition (a_1 and a_2 arbitrary constants)	$a_1x_1(t) + a_2x_2(t)$	$a_1X_1(f) + a_2X_2(f)$
2. Time delay	$x(t - t_0)$	$X(f)e^{-j2\pi ft_0}$
3a. Scale change	$x(at)$	$\lvert a\rvert^{-1}X\left(\frac{f}{a}\right)$
b. Time reversal	$x(-t)$	$X(-f) = X*(f)$
4. Duality	$X(t)$	$x(-f)$
5a. Frequency translation	$x(t)e^{j\omega_0 t}$	$X(f - f_0)$
b. Modulation	$x(t)\cos\omega_0 t$	$\frac{1}{2}X(f - f_0) + \frac{1}{2}X(f + f_0)$
6. Differentiation	$\frac{d^n x(t)}{dt^n}$	$(j2\pi f)^n X(f)$
7. Integration	$\int_{-\infty}^{t} x(t')\,dt'$	$(j2\pi f)^{-1}X(f) + \frac{1}{2}X(0)\delta(f)$
8. Convolution	$\int_{-\infty}^{\infty} x_1(t - t')x_2(t')\,dt'$	$X_1(f)X_2(f)$
	$= \int_{-\infty}^{\infty} x_1(t')x_2(t - t')\,dt'$	
9. Multiplication	$x_1(t)x_2(t)$	$\int_{-\infty}^{\infty} X_1(f - f')X_2(f')\,df'$
		$= \int_{-\infty}^{\infty} X_1(f')X_2(f - f')\,df'$

End of Paper